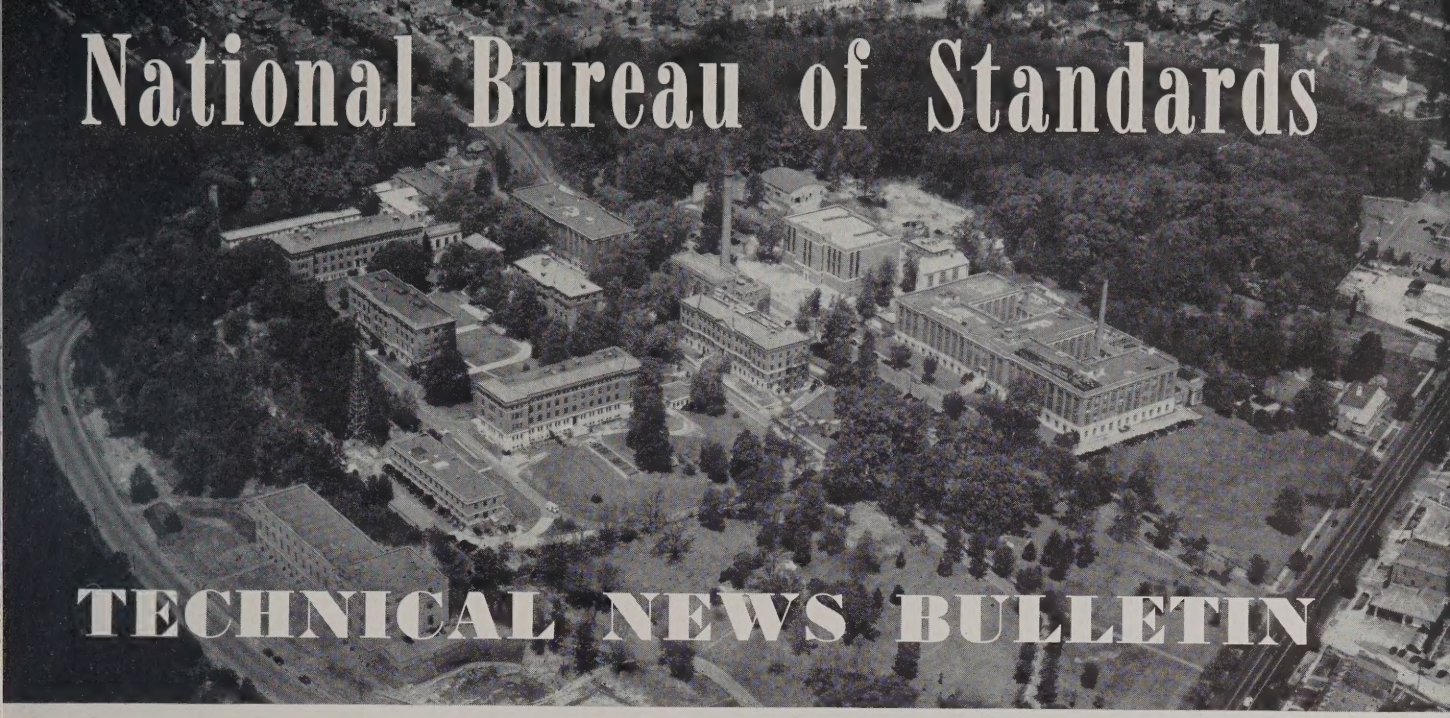

VOLUME 31 FEBRUARY 1947 NUMBER 2

High-Speed Electronic Digital Computers

The National Bureau of Standards has been commissioned by the Bureau of the Census and the Office of Naval Research to construct two high-speed electronic digital computing machines that may well revolutionize the methods of classification and compilation of data and of numerical computation.

The computers are to be of the automatically sequenced digital type. Automatic sequencing reduces the intervention of a human operator to a minimum, while electronic rather than electromechanical or relay-type components assure a speed in the arithmetic operations of addition, subtraction, multiplication, and division measured in millionths of a second.

The machines will be capable of handling huge compilation problems and of solving the most complicated differential equations in engineering and physics. They will perform, upon instruction, predetermined sequences of calculations running into the hundreds of operations without the intervention of human operators. The result will be the solution of problems in days that would take years if attempted by present standard machines.

The machines under construction are to have built-in "intelligence" capable of distinguishing between orders and data presented in coded form. Design specifications call for internal memories in which 5,000 or more 10 or 12 digit numbers and orders combined can be stored. The machines will be able to transfer numbers and orders between their internal organs and memories within a few millionths of a second. Numbers and orders will be taken automatically from a continuous storage medium in the form of a film or tape, and the machines will know when to depend on their internal memories and when to obtain information from this external tape. At predetermined steps in computation, the computers will be able to choose and execute alternative orders upon the basis of the results of the preceding steps. They will know when computations have been completed to a preassigned accuracy and will either print the results at that time or store them on an external tape for printing later.

At the present time, a typical census problem involving the multiplication of 100,000 pairs of five-digit numbers followed by summing the products takes approximately 12 working days exclusive of card handling and data punching. The electronic digital machine for the Census Bureau will handle the same sequence in 10 minutes at the most. A problem of great importance to the Navy is the determination of vibration characteristics of ship machinery and aircraft. One such problem, arising in the flutter analysis of aircraft wings, now takes about 5,000 machine hours by the most efficient method available. With the projected Navy computer, the problem can be solved in 1 hour.

During the recent emergency various Federal agencies pioneered in the development and use of ultra-high speed computing machinery. The applications of such machinery ranged from numerical solutions of problems involving nuclear physics, hydrodynamics, electromagnetic wave propagation, the computation of firing tables, the application of statistical sampling theory and the like, to inclusion as components in

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missile flight simulators and fire control apparatus. The need for high computation speeds was extremely urgent, and the digital machines developed to meet it played a significant role in shortening the conflict.

Federal activity in the computing field stemmed principally from the efforts of the War and Navy Departments to acquire computing machinery constructed specifically for critical wartime computation needs. There were three significant developments in this period: (1) an electromechanical computing device (the IBM sequence controlled calculator) of the Harvard Computation Laboratory, (2) relay type computing machines of the Bell Telephone Laboratories, and (3) an electronic computing machine (ENIAC) of the Moore School of Engineering of the University of Pennsylvania.

Current Program

A significant result of the intensive development and use of the high-speed computing machines during the war is that designers have been provided with operating data that would normally have required many years for accumulation. Experience now indicates rather clearly both the merits and the deficiencies of existing machines. The consensus of expert opinion is that the potentialities of electronic machines surpass those of the electromechanical and relay types and that further development should probably be limited to the electronic field. It is also agreed that an unparalleled opportunity for design improvements is at hand and that electronic digital computing machines can be constructed that will far exceed the ENIAC in speed and flexibility.

Electronic digital computing machine development requires the cooperation of two groups: mathematicians, responsible for the mathematical performance requirements and for organizing the mathematical logic; and physicists and engineers, responsible for developing the basic functional organs and for the engineering design integrating these organs into a unit capable of performing the prescribed tasks. The mathematical phases of the program are under the direction of J. H. Curtiss, Assistant to the Director and in charge of the Bureau's mathematical and statistical work. The electronic phases are conducted by the electronics section of the Ordnance Development Division under the direction of Harry Diamond, chief of the division.

The program involving the Census and Navy machines includes contractual relations with industry. For example, Raytheon Corporation and the Electronic Control Co. have active roles. Both organizations have experts in the field; leaders of the latter are J. W. Mauchly and J. P. Eckhart, who were the developers of the ENIAC. A special program is also under way at the Bureau for the Army Ordnance Department on development of basic organs for computing machines. Close relations exist with the Institute for Advanced Study, Princeton, under Dr. John von Neumann, and the Moore School of Engineering, under Dean Harold Pender. Such diversified cooperation among these principal exponents of electronic digital computers will ensure development of the most highly advanced machines to meet current needs.

The two machines to be built by the National Bureau of Standards will speed up the Bureau of Census tabulations and compilations and expedite the research program of the Navy Department. The new Census machine will introduce gains of a substantial character. Economy will be affected not only in the cost of tabulation of data but also in the time required to compile census information. In addition, as a result of quicker processing of raw data, the time between collection of data and reporting it will be shortened. The Navy machine will be available to the armed services and to other government agencies as well as private industry.

Computing Laboratory

According to present plans, the Navy machine will be located in a large general-purpose computing laboratory, which will also be equipped with standard business-type computing machinery and will be operated by the National Bureau of Standards. This laboratory will be staffed with personnel trained in the methods of numerical analysis. It will contain an analytical section which will conduct basic research in applied mathematics and will assist in formulating problems mathematically and preparing them for numerical solution.

The idea of developing such a laboratory was originally suggested by the Office of Naval Research as a

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E. U. Condon, *Director*

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means of expediting research for defense. This type of computing laboratory is a natural outgrowth of the present highly successful Mathematical Tables Project of the National Bureau of Standards, consisting of a large computing group located in New York City, and currently supported with funds transferred by the Office of Naval Research. It was established about 10 years ago to satisfy the need for more complete and more accurate tables of mathematical functions. Over 28,000 copies of the various tables of the Project are now in use, and the annual demand runs at the rate of about 3,500 volumes.

The Project emerged from the war a fully rounded and versatile computing laboratory with substantial experience in the field of numerical research as well as in the construction of tables. After its incorporation in the larger laboratory mentioned above, two automatic high-speed digital calculators will be added to its present complement of electric desk calculators, electric adding machines, automatic electric accounting machines, and IBM punch card machines. The automatic calculators will probably shift the emphasis of the work more strongly than in the past to the analytic aspects because automatic machines will require a vast amount of additional mathematical theory of numerical analysis. The Bureau, in cooperation with the Office of Naval Research, is planning a broad program of research oriented toward such problems, and this program is expected to make a permanent contribution to the scientific resources of the nation.

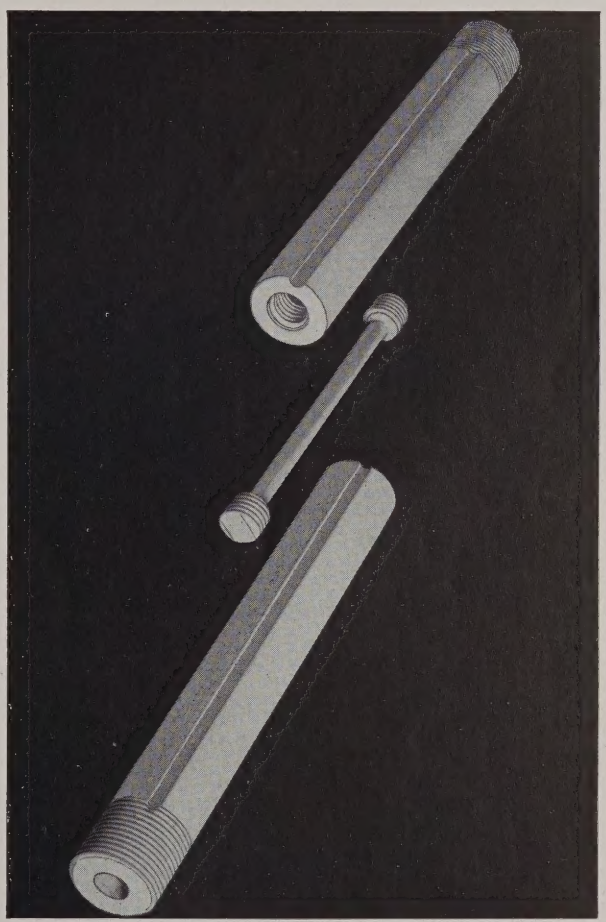
High-Temperature High-Strength Porcelains

New all-crystalline porcelains, having exceptional mechanical and dielectric strength at temperatures extending up to 2,000° F, have been developed in the Bureau's Porcelain and Pottery Laboratory. Such porcelains are particularly valuable for sustaining loads at elevated temperatures, as electrical insulators at elevated temperatures, and as insulators for such special applications as aviation spark plugs and radar transformers.

The composition of these new porcelains is characterized by the use of such materials as alumina, beryllia, zirconia, and thoria, with minor additions of other metallic oxides, and by the absence of silica. A representative high-beryllia porcelain contains 84 percent beryllia and 8 percent zirconia, with small amounts of lime and alumina; a typical high-zirconia composition is 80 percent zirconia, 10 percent beryllia, and 10 percent magnesia.

In 1940 the Bureau began a series of investigations to develop glass-free ceramic bodies of the porcelain type which would have simple compositions favorable to high mechanical strength, particularly at elevated temperatures, and good resistance to thermal shock, properties not found in the conventional porcelains. The usual porcelain composition includes feldspar, which reacts as a flux with clay and silica, dissolving them in part to produce a viscous liquid. The liquid fills the interstices between the crystalline phases of the mixture, and upon cooling, becomes a matrix of glass upon which the strength of the porcelain is largely dependent. This glass will soften and deform under stress, at temperatures much lower than the temperatures at which the crystalline phases liquefy.

The work, initially undertaken as a fundamental contribution in the field of ceramics, was accelerated by the wartime demands for a material that would resist deformation at temperatures up to 2,000° F, for use in jet propulsion and gas turbine engines. A decided advantage of ceramic materials for this purpose, if other properties are satisfactory, is their low density as compared with the high-temperature metallic alloys. Accordingly, the investigation was extended under the sponsorship of the National Advisory Committee for Aeronautics to include strength and creep characteristics in pure tension at temperatures ranging from 1,500° to 2,000° F. On the basis of preliminary tests, six compositions were chosen for further study, and tension specimens were made commercially from specifications furnished by the Bureau.



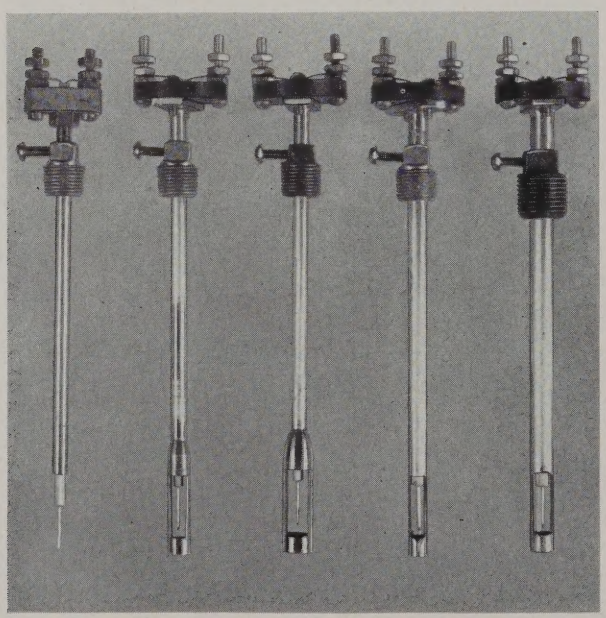
Porcelain specimen (center) for tension tests at elevated temperatures, and ceramic adapters (top and bottom) through which stress is applied. Assembly of specimen and two adapters is such that the outer ends of the adapters protrude from the furnace and screw into brass heads that connect to a loading device.

Tensile tests require perfect alinement of the stressing members and freedom from bend of the specimen. Furthermore the supporting members must be of a material that will withstand the stresses and temperatures involved. Therefore adapters, through which stress may be applied to the specimens, were perfected. These adapters are porcelain cylinders (all of the adapters were made from the same experimental composition), threaded internally on one end to receive the tension specimens and externally on the opposite end. The assembly of tension specimen and two adapters is of such length that the outer ends of the adapters protrude from the furnace. The adapters, in turn, screw into brass heads which connect through universal joints to the loading device.

Creep or extension of the specimens under load is indicated by a gage similar in principle to those used at the Bureau for measuring creep of metals. Fabricated from platinum-rhodium alloy, it consists of a cut-away tube and a wire that moves freely in this tube. When cemented to the specimen in two places, relative movements of the specimen are determined by observing reference lines on the wire and on the cut-away section of the tube. By a special optical apparatus—an illuminated Gaertner extension-viewing device provided with a filar micrometer eyepiece—measurements of the creep may be observed with a precision of 1 micron, and readings interpolated to 0.1 micron. Two gages, 180 degrees apart, are used in each test.

In the early phases of the body development work, preceding the creep tests, a furnace was designed for the high temperatures required. Capable of accurate control at high temperatures, the furnaces are electrically heated with special oxide resistors that are stable in an oxidizing atmosphere. Furnaces have been built that have attained a temperature of 3,700° F. By means of a combination of manual and automatic temperature controls, an average air temperature may be maintained over the entire gage length to ±5 deg. F.

Research and development are continuing in the field of high-temperature porcelains, for ceramics offer definite promise of usefulness in the high-temperature regions where metallic alloys are no longer serviceable.



Pyrometers utilizing silver-shielded thermocouple junctions provide highly sensitive temperature measurements in high-velocity gas streams of gas turbines and jet engines. Steel-guarded junctions give substantially the same results as the unguarded type (extreme left).

Pyrometer for Gas Turbines and Jet Engines

With the recent development of gas turbines and jet engines as practical power plants has come a need for accurate and responsive temperature-sensing instruments. Such instruments would serve not only for evaluating engine efficiency, but also for protecting experimental and service equipment from damage by excessive temperature of various parts. An improved pyrometer for measuring the temperatures of these high-temperature high-velocity gas streams has been developed by Andrew I. Dahl of the Bureau's Temperature Measurements Laboratory in cooperation with the Bureau of Ships, Navy Department.

The new pyrometer consists essentially of an ordinary thermocouple junction around which is pressed a small, light, silver shield. The junction, made by conventional methods, is inserted one-half inch into a silver tube ¾ inch long that is slightly flattened. A thin mica strip is then placed within the silver tube on each side of the junction and the assembly is pressed to form a rigid unit with good thermal contact between shield and junction. The main problem in measuring the temperature of the hot gases is preventing the transfer of heat to or from the thermocouple junction by radiation. The shields previously used for this purpose are not only bulky and slow to respond to changes in temperature, but also offer considerable obstruction to the stream of gas. The use of a silver shield overcomes these limitations because silver, being a good reflector and a poor emitter for radiant-heat energy, keeps the temperature of the shielded junction nearly the same as that of the gas.

The new device was found accurate to within 5 degrees in experiments utilizing a stream of gas at 1,500° F flowing with a velocity of 250 feet per second through a pipe with walls at 1,200 degrees. In addition to high accuracy, laboratory tests indicate that this pyrometer responds quickly to changes in temperature. It is simple to construct and easy to install, and the new junction creates a minimum of disturbance to gas flow.

The maximum dimension of the shielded junction need not exceed the diameter of the porcelain tube used to insulate the thermocouple wires from each other. Various types of steel protecting tubes can be used to protect the unit without loss of accuracy or sensitivity. Several of the new instruments have been constructed and sent to commercial turbine manufacturers for service tests in full-scale operating turbines.

Printing Electronic Circuits

The printed electronic circuit, representing the perfection of a method of printing wiring and circuit components on an insulated surface, is one of the most important of the new processes and technics evolving from research and development during the war. The new technics, developed by the National Bureau of Standards in cooperation with electronic manufacturers for the tiny generator-powered radio proximity fuze, promise to simplify production methods, and to accelerate the manufacture of cheaper, more compact, and more uniform electronic equipment.

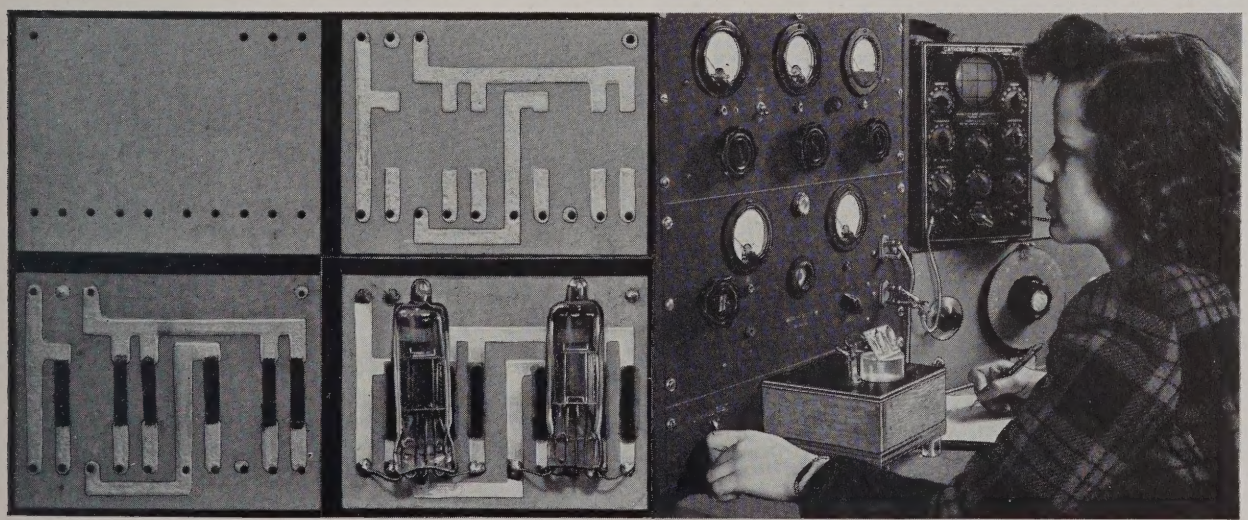
The methods are applicable in the design of numerous industrial and commercial devices where extreme ruggedness and small size are imperative. By means of the printing process the electronic circuit of a conventional radio—now characterized by a maze of wires, resistors, inductors, and condensers—may be replaced by a compact circuit printed on a small flat plate, eliminating much of the third dimension and making it simple to check and repair. Other specific applications lie in the fields of pocket radios, personal radio telephones, miniature hearing aids, meteorological instruments, and various miniature electronic control circuits.

Present investigations at the National Bureau of Standards of the various means available for reducing the size of electronic assemblies and for mechanization of chassis wiring reveal a number of feasible and practical electronic printing methods. Variations of the stenciled screen printing process include hand printing or spraying of the components and leads on suitable surfaces. Another method involves the use of photography and an abrasive blast. A third is an adaptation of the chemical methods of silvering mirrors. Mechanical processes include metal spraying, metal sputtering or evaporation, the use of foils, and stamping. As an example, loop antennas are now stamped out in a single operation by a variation of the printed wiring technics and have shown improved performance over wire-wound loops, in addition to reduced cost of production. The principal effect of these methods is to reduce electronic circuit wiring to two dimensions. The effect is enhanced where it is possible to employ subminiature tubes and compact associated components.

Compact Circuit by New Technics

Four simple technics are the key to the electronic printing process which led to the design of control circuits capable of meeting the space limitation and ruggedness requirements of the VT fuze. First, the circuit wiring and inductors are painted or stencilled with silver paint on a chassis or base material, such as a plate of steatite. Second, the resistors, in the form of a carbon and resin mixture, are stencilled or sprayed on the plate through masks that locate them accurately between designated end tabs. The small disk-type capacitors, of high dielectric ceramic, are then applied directly to the wiring on the plate. Last, other components, such as tubes, are fitted into properly located holes in the ceramic and soldered in place. In this manner, a compact electronic circuit assembly, readily adaptable to high production technics, is obtained.

Any insulating surface may be employed as a base plate for the wiring. Thus, electronic circuits may be printed on glass, porcelain, plastics, cloth, paper, or any material having suitable insulating properties. Steatite, a hard and dense ceramic material, is well adapted for use as a base material. In fabricating, carefully selected ground talc and small percentages of clay, fluxes, and organic binders are worked, with the addi-



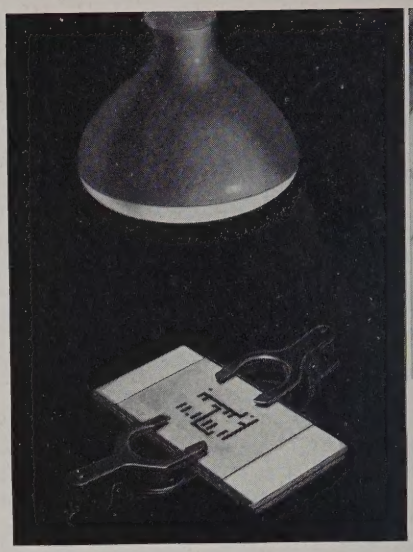
Four simple technics (left) are followed in making the printed electronic circuit: blank steatite plate and plate with circuit wiring applied (upper), with the addition of resistors and the assembled unit with miniature tubes (lower). A miniature printed circuit amplifier is tested (right) to measure characteristics of the circuit.

tion of water, into a uniformly plastic condition. The mixture is then molded into plates under pressures between 5 and 10 tons per square inch. The plates are dipped into glass-forming materials and fired in kilns at a temperature of about 2,400° F, producing a hardness approaching that of sapphire. The resulting material, steatite, is unaffected by water, solvents, or even acids—important factors in its electrical use.

The next step in printing the circuit is to apply a pattern of silver lines to the ceramic, either directly with a brush or by using a silk or metal stencil. The stencil is produced by coating silk or metal screens with a substance such as gelatin or polyvinyl alcohol which is made photosensitive by treating with potassium dichromate. A sheet of paper bearing the desired wiring pattern is held tightly against the screen and exposed to strong light. Exposure "fixes" the chemicals on the screen except for those portions beneath the wiring diagram. The silk or metal is then washed in water, and those parts not exposed to light dissolve in the water and wash out, leaving openings in the screen corresponding to the desired wiring diagram.

The stencil is laid over a clean ceramic plate and silver ink or paint is brushed over it. An impression on the plate exactly like the wiring of the circuit is thus obtained, but instead of copper wires there appears a group of silver lines. The silver paint consists of very finely divided silver or silver oxide mixed with a binder to make a paste and thinned with a solvent such as acetone. After impression of the pattern, the

Conductors, inductors, and resistors are bonded permanently to the ceramic plate by firing in a furnace. Silver ink components (conductors and inductors) are heated to approximately 1,400° F and graphite ink components (resistors) to 300° F.



Preparing a stencil graphically (left) printed electronic c inductors (right) a by forcing silver (center). Resistor manner, using grap

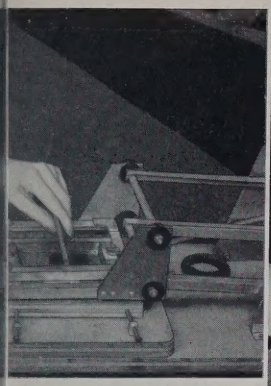
plate is heated to a temperature between 1,300° and 1,500° F, bonding the silver permanently to the ceramic. Paints have been developed which require firing at considerably lower temperatures if desired. The principal advantage which results from higher temperature firing is exceedingly strong adhesion to the plate.

The resistors are sprayed or painted through another stencil into their proper places or applied with a brush. The resistor paint consists of a conducting material such as powdered graphite, and an inert or nonconducting material such as mineralite or powdered mica. These materials are mixed with a binder to form a paste or heavy ink. The resistance may be varied by varying the amount of inert filler or suitably selecting the length, width, and thickness. After the resistor paint has been applied, the plate is placed in an oven at 300° F to cure the resistors so that their values will not change with use. A special resin coating is painted over the resistors to protect them against humidity and other effects.

High-dielectric capacitors are then soldered in their proper positions on the ceramic, using low-temperature solder. For ordinary radio and electronic application, the capacitors are from $\frac{1}{8}$ to $\frac{3}{8}$ of an inch in diameter and less than $\frac{4}{100}$ of an inch thick. The new subminiature vacuum tubes complete the miniature subassembly.

Economy and Size Reduction

Uniformity of production, reduction of assembly and inspection time, and reduction of line rejects make the electronic printing processes industrially attractive because large reductions in cost are possible. In present assembly line practices, wiring represents one of the larger items of production cost. Wires must be cut to length, bent into shape, and individually soldered or connected. As there are close to a hundred soldering operations in the average household radio set, the cost of labor and materials for soldering alone represents an important item. The new wiring processes should eliminate 30 to 60 percent of the soldering



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needed for conventional circuits. A single operator on a production line could conceivably make thousands of printed circuit plates each day.

In addition to increased economy of production, there are other important advantages to be gained from the use of these technics. A properly designed printed circuit offers size reduction unobtainable by other means. Examples of equipment to which the principles might be directly adaptable include the manufacture of I-F strips for radar equipment, control circuits in pilotless aircraft, portable radio transmitters and receivers, hearing aids, electronic recording equipment, special research instruments and other subminiature electronic control devices. A proposed electronic "memory" circuit imbedded in a suitable plastic compound, small enough to be installed in the base of a regular cradle-type telephone and tough enough to withstand rough handling, would eliminate almost entirely the waiting period between dialing and completion of the circuit at the central telephone office. With such a system, the subscriber would dial his number before lifting the handset from the cradle, and the information stored in his set would be transmitted to the central office in 0.1 second after the instrument is lifted. Thus the equipment of the central office would be tied up only 1/130th as long as with the present system, and the subscriber's call expedited.

Plug-in subassemblies made with printed circuit technics offer advantages not yet fully realized. Such subassemblies can be constructed as integrated units, small, compact, and ready to plug-in much like single radio tubes at present. These units also offer many maintenance advantages, factors important in rural and foreign markets. Principal units of a set can be removed wholly, tested, and replaced in the same manner as tubes are handled. Such units should be useful in areas where skilled repairmen are not available and in military and other applications where it is necessary to do trouble shooting under difficult conditions. With all major subassemblies wired in plug-in fashion, the repairman can, if necessary, replace all the subassemblies in the set, taking the old units back to the laboratory for checking. In this way it would be possible to have several independent circuits—such as phonograph amplifier, A. M. receiver, F. M. receiver, and television set—all in a small cabinet.

Related Developments

Several related developments in electronics, as far as size reduction is concerned, make feasible a remarkable miniaturization of complete circuits. These include the development of subminiature tubes comparable to standard radio tubes and miniature capacitors and rectifiers. At the same time, the art of printing circuits has advanced to the point where complete circuits can be printed on cylinders surrounding a tube or on the tube envelope itself. Subminiature radio transmitters of these types have already been constructed by the National Bureau of Standards. A typical transmitter, designed to operate in the VHF band and capable of extension to the UHF, employed coils painted on the tube envelope with silver ink, a 47,000-ohm grid leak added with graphite paint, and a 7.5 micromicrofarad ceramic capacitor connecting the plate and grid coils. The entire transmitter is no larger than a small lipstick case; a tiny microphone and battery complete the unit. Finally, the development of special casting resins permits the potting of entire electronic assemblies in light, rugged units highly resistant to atmospheric conditions.

Printed resistors are tested at the Bureau over a temperature range of −76° F to +140° F with humidities up to 100 percent. Such resistors have been shown to have stability under these conditions comparable to or better than conventional resistors.

Betatron Research in Multimillion-Volt Range

Plans have been completed for the erection of two betatrons at the National Bureau of Standards, enabling Bureau scientists to extend research, measurements, and standards development into the 50- and 100-million-volt range.

Two immediate problems calling for extensive investigation are the determination of measurement technics and the formulation of precautionary principles in the use of the betatron for cancer treatment.

For the past 20 years, the National Bureau of Standards has played a central role in the development of standards for X-ray dosage measurement and protection. The field has been covered thus far only up to one and a half million volts. For this purpose, the Bureau now has one of the best equipped X-ray laboratories in the world. Because of its facilities and its experience in the field of radioactivity as well as X-rays, outside organizations such as the radiological and medical groups, the Manhattan District, and the International Commission on Radiation Protection and Radiation Dosage, are looking to the National Bureau of Standards for extension of X-ray measurement activities into the newly opened multimillion-volt range.

The betatron is a device for producing electrons or X-rays of extremely high energies and frequencies. Both as an X-ray device and as an electron-beam generator, the betatron has unusual potentialities in the fields of medical, biological, industrial, and nuclear research.

It consists essentially of a large alternating-current magnet, in the center of which is an evacuated tube having a doughnut shape. Electrons are admitted into this tube, where they describe a circular orbit under the influence of a magnetic field, making hundreds of thousands of revolutions in a fraction of a second. When these energized electrons strike a target within the tube, extremely penetrating X-rays are produced. The tube may be arranged so as to emit electrons directly, and electron beams having a range of several feet may be produced in air.

Medical and Industrial Radiation Protection

As a medical tool, the betatron can provide X-rays suitable for cancer treatment under conditions long dreamed of but never realized. With 20-million-volt radiation, it is possible to deliver to a subsurface tumor all the radiation it can stand and yet not seriously jeopardize the skin. Recent research has indicated that the electron beam may also be used directly in therapy, for the beams have the property of passing through the surface and subsurface tissues with negligible absorption. Yet at a controllable depth, all of the energy of the electron beam is given up and absorbed by a tumor.

During the war, the betatron came into limited industrial use for the inspection of heavy-metal objects such as guns, shells, and large castings. Photographic exposures could be made through a foot or more of steel in a matter of seconds, using a betatron, whereas the older methods utilizing radium required hours.

The problems of protection in both the medical and industrial applications of high-voltage radiation are immeasurably greater in the multimillion-volt range than in the lower regions heretofore encountered. Heavy protective barriers and expensive over-all installations are required, but the exact protection measurements and technics are as yet unknown. One of the aims of the Bureau study is to discover the necessary thicknesses and types of construction that will give maximum protection with lowest over-all costs. Industrial use, in particular, presents difficulties not encountered in the medical applications, and the establishment of safe working conditions for industrial betatron use is one of the principal objectives.

Betatron in Nuclear Research

The betatron is also an important tool in nuclear or atomic research. Many nuclear transformations are brought about simply by exposing materials to the powerful X-ray beam. It is planned to make a systematic study of these transformations, which constitute a phase of atomic research virtually untouched at present.

Some of these transformation processes may take place when the human body is exposed to radiation, and it therefore becomes essential that they be thoroughly understood in connection with any biological or medical experiments. An understanding of these processes will also contribute materially to the general fund of atomic knowledge.

In 1946 Congress authorized and appropriated funds for the construction of a special building and the installation of a betatron at the Bureau.

The betatron was designed to operate up to 50 million volts, although the building was designed to house much larger equipment as it became available, equipment up to 150 million volts and probably higher. While the building designs have been completed by the Public Buildings Administration, the program has been retarded by the sharp increase in building costs since the appropriation estimates were made. Further action of Congress is waited before proceeding with the construction program.

Design Features

The main chamber in which the betatron is to be housed, and the X-rays produced, will be completely buried underground and covered by several feet of concrete and earth. This is to prevent any direct radiation from escaping and harming nearby workers.

The sensitive measuring equipment will be housed in an adjoining smaller room. In combination with these two rooms, facilities have been designed for determining the protective values of concrete and other materials, under conditions that will permit of their

broad interpretation in the medical and industrial X-ray field.

This latter point is of particular importance, since it is almost impossible to obtain this information with any of the existing or contemplated betatron installations. Requirements for this work are such that the buildings must be specially designed and constructed just for the purpose of determining protective values. The operators of the equipment will be separated from the betatrons by a concrete labyrinth and a 5-foot-thick concrete wall, operating all equipment by remote control devices.

The first betatron planned will operate up to 50 million volts. Although this is not the largest device available, it is essential to provide for the production of X-rays from the relatively low voltage of 1 million up to the higher 50 million volts. The region between 1 and 20 million volts is of extreme importance in medicine and biology. Large instruments, unfortunately, cannot operate successfully in this lower range.

The 1947 budget request calls for the addition of a 100-million-volt betatron that will enable the Bureau to extend its studies above the 50-million-volt limit of the smaller instrument. It is in this higher region that atomic and nuclear phenomena begin to become more evident.

Broad cooperative programs of research are planned with the National Cancer Institute and the Carnegie Institution of Washington. The National Cancer Institute has excellent facilities for biological investigations, while the Carnegie Institution has available both a cyclotron and a Van der Graff generator. Acquisition of betatron facilities by the National Bureau of Standards, in conjunction with its established radioactivity and X-ray laboratories, serves to round out the biological, medical, and biophysical radiation facilities of the Washington area in the high-energy radiation range.

WWV Technical Broadcast Services

Radio station WWV, of the National Bureau of Standards, is broadcasting six important technical services to the nation and five to the world, 24 hours a day.

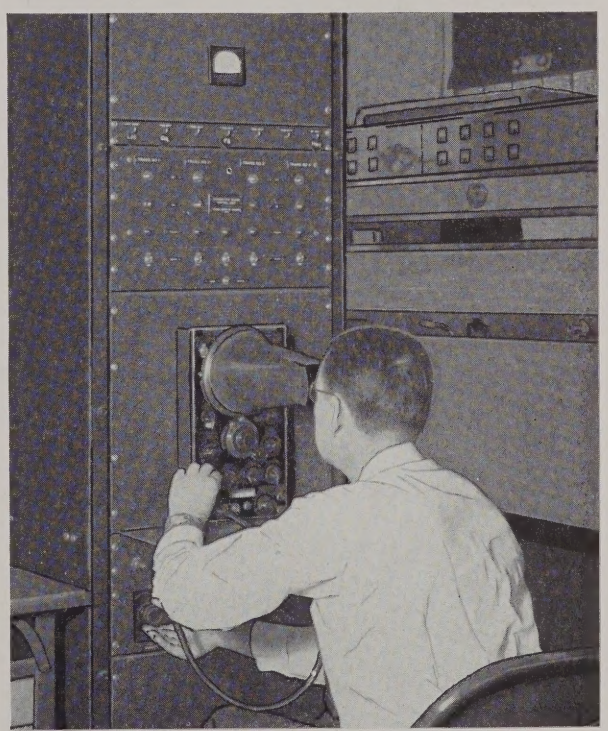
Standard radio frequencies, time announcements, standard time intervals, the standard musical pitch of 440 cycles per second, and standard audio frequencies are transmitted continuously to the corners of the earth. As an additional service ionospheric and radio propagation-disturbance warning notices are broadcast twice each hour, stating whether or not radio disturbances are expected.

Eight transmitters are used on frequencies of 2.5, 5, 10, 15, 20, 25, 30, and 35 megacycles per second. All the frequencies are broadcast continuously except 2.5 megacycles, which is broadcast only at night. Because of the range of frequencies provided, reliable reception is in general possible throughout the United States and North Atlantic Ocean at all times, and fair reception throughout the rest of the world.

The basic component of all the services, with the exception of the radio propagation disturbance warnings, is a quartz-crystal unit with a series-resonance frequency of approximately 100,000 cycles per second. Using electron-tube circuits, the crystal oscillates continuously and the resulting frequency is multiplied and divided to give the appropriate frequencies for the five services. Three separate crystal units and associated apparatus are maintained at the station. As the entire service depends upon the maintenance of constant frequency, the crystal units are sealed in painstakingly insulated boxes and kept in a vault approximately 25 feet below the surface of the earth, under conditions of constant temperature and humidity.

The national standard of frequency, of which the Bureau of Standards is the custodian, is fundamental to much of the work in radio, electronics, acoustics, and other fields where measurements require accurate frequencies. Any desired frequency, including those throughout the microwave region, may be precisely measured, by reference to the standards broadcast by the station, with the aid of one or more auxiliary oscillators, harmonic generators, and radio receivers. The accuracy of each of the transmitted radio and audio frequencies is better than 1 part in 50 million.

Eastern Standard Time is announced in International Morse Code every 5 minutes, using the 0 to 24 hour system with 0000 at midnight. The exact moment to which the time refers is the moment of interruption of the audio frequencies of 440 and 4,000 cycles

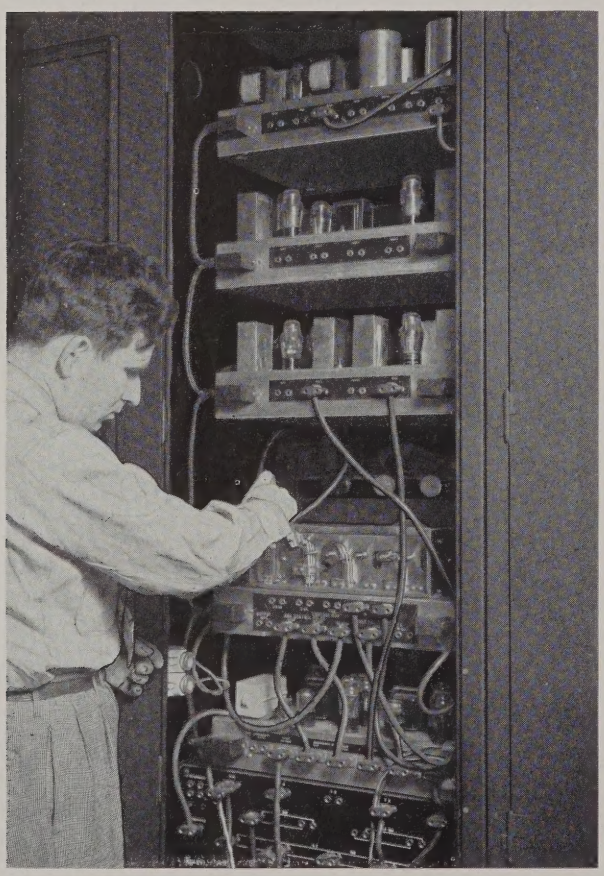


The transmitter monitor panel of radio station WWV indicates the operating condition of each transmitter through a series of lights on the panel. Modulation is adjusted and wave forms are checked by viewing both on a cathode-ray oscilloscope.

per second. This moment is in precise agreement with the basic time service of the U. S. Naval Observatory, and the audio frequencies are interrupted for 1 minute to allow for the time announcement, for station identification by voice at the hour and half hour, and to afford an interval for checking radio frequency measurements free from the presence of audio transmissions.

The standard time intervals, transmitted on each of the carrier frequencies, utilize a special pulse of 0.005-second duration broadcast every second. Heard as a faint "tick" in the background of the broadcast, the 0.005-second pulses working each second provide an indispensable standard time interval for purposes of physical measurements, for quick and accurate calibration of timing devices, and for the adjustment of very low frequency oscillators. Intervals of 1 second, as broadcast, are accurate to one millionth of a second. One, 4 and 5 minute intervals, accurate to one part in 50 million, are marked by the beginning and ending of the periods when the audio frequencies are off, and are synchronized with the series of seconds pulses. The 59th in each series of 60 seconds pulses is omitted to designate the end of each minute.

The standard musical pitch of 440 cycles per second—A above middle C—is broadcast for 4 minutes and interrupted for 1 minute. This sequence is continuous on each of the radio-carrier frequencies. The service is used by musicians and those concerned with the manufacture or maintenance of musical instruments. Since 1925 that frequency has been the standard musical pitch in the United States music industry.



WWV's audio-frequency and time-interval generating equipment. Duplicate spare units are maintained. 100,000 cycles per second from the standard oscillator supplies this unit, which also provides synchronization for auxiliary equipment.

A warning of radio propagation disturbance is broadcast in code on each of the standard radio-carrier frequencies at 20 and 50 minutes past the hour. If radio propagation disturbance over the North Atlantic is expected or is in progress, a "warning", or series of six "W's" in telegraphic code, follows the time announcement; if no disturbance is in progress or expected, a "no warning", or series of eight "N's", follows the time announcement.

A warning means that ionospheric and radio propagation disturbances are anticipated within 12 hours or are in progress, with their most severe effect on radio transmission paths crossing the North Atlantic. These are the paths which lie in or near the northern auroral zone (the region of maximum occurrence of aurora) which is the seat of most ionospheric disturbance.

A radio-propagation disturbance is characterized by low-received intensities, accompanied by flutter or rapid fading and often a complete fadeout on the frequencies normally used at a given time of day. By shifting to lower-than-normal frequencies for the time of the day during which a storm is predicted, it may be possible to get signals through, although with lower-than-normal intensity. Because of the increased auroral-zone absorption during the disturbance, however, usable transmission may be impossible on any high frequency. Moreover, direction-finding equipment is likely to be unreliable during such a period.

Users of the technical broadcast services select the frequency that reaches them best, either by empirical observation, or by making use of the available technics for prediction of best frequencies.

Although a great number of variables affect radio-wave propagation and the distance range, the National Bureau of Standards has developed technics for the prediction of best frequencies over any specific path during any future month. By means of such technics and the prediction service of the National Bureau of Standards, it is possible for a user to prepare for his locality a graph or table showing the best frequency for any period of the day in any month, 3 months in advance. Basic radio-propagation predictions and instructions for using them are prepared by the staff of the Central Radio Propagation Laboratory of the Bureau of Standards under the title "Basic Radio Propagation Predictions, Three Months in Advance", and are available from the Superintendent of Documents, U. S. Government Printing Office, at the rate of 15 cents per copy or $1.50 for a year's subscription.

New Laboratory to Test Geiger-Müller Counters

A new laboratory to test Geiger-Müller counters and associated electronic measuring equipment has been established in the Radioactivity Section of the National Bureau of Standards. Called into being by the growing demand for reliable, stable instruments, the laboratory will test performance qualities, utility, and construction of counters now being manufactured.

The fields of science dealing with radioactive matter and isotopes have grown far beyond that of physics to include biology, chemistry, and medicine, in addition to fast-developing industrial uses. In all of these areas of investigation, the Geiger-Müller counter has become a critical piece of equipment, although commercial production has been undertaken only in the past 7 or 8 months. Some specific applications of the counter include the control of dosages when radioactive material is used medically and the tracing of material introduced into plants in connection with biological investigations.

Research uses for the counters include detection and numerical measurement of particles emitted in experiments involving nuclear radiation, transmutation, and disintegration.

Many varieties of counters have been made commercially and in research laboratories. The problem of construction involves not only stability and accuracy, but also adaptation of the basic idea to the specific purposes to which the device will be put.

Because of the possible types of counters available, preparation of specifications for a particular instrument may be difficult for the researcher lacking the background of the physicist or the electronic engineer. The problem is further complicated by the fact that it is unusual for successive counters made even by the same manufacturer to be alike in every detail. Improvements and advances are made rapidly in this field and can quickly be incorporated in a counter under construction.

The new laboratory, through its testing program, will attempt to bridge the gap between the manufacturer and the user, providing for expert determination and study of efficiency, stability, uniformity, and sensitivity of counters. Aid will be rendered to purchasers, by assistance in the formulation of specifications, and to manufacturers by the accumulation of test data and by determining the types of counters necessary to various fields of scientific research.

Because of the lack of uniformity in types and design of the counters now becoming available, no attempt can be made at present to set up standard specifications for them, and the uniqueness of each instrument now being manufactured controls the immediate program outlined for the new laboratory. It is expected that cooperation between the laboratory, purchasers, and manufacturers will gradually achieve a background of experimental and operational data leading to standard types of equipment.

NBS Scientists

Dr. Hugh L. Dryden, Associate Director of the Bureau, was recently elected one of four United States representatives to the International Committee at the Sixth International Congress for Applied Mechanics held at the Sorbonne, Paris. The International Committee is the managing body of the Congress, which is concerned with international cooperation, advancement, and standardization of the sciences of applied mechanics.

Dr. Harvey Lincoln Curtis, physicist on the Bureau staff since 1907, chief of the Interior Ballistics Section and for 32 years chief of the Inductance and Capacitance Section, retired on December 31. Although he is best known for research in the field of electricity, particularly absolute electrical measurements, Dr. Curtis assumed responsibility during both world wars for interior ballistics research at the Bureau, and in this capacity directed development of an instrument that measures, at a single firing, almost the entire range of phenomena inside a gun. Dr. Curtis has also been connected with research on electrical insulating materials, mica condensers, and various other electrical problems and devices, as well as the photography of projectiles in flight.

Kenneth A. Norton, an authority on radio wave propagation, has been designated chief of the recently established Frequency Utilization Research Section of the Central Radio Propagation Laboratory. Mr. Norton rejoins the Bureau staff from the War Department where he has served as a consultant in radio propagation. The Frequency Utilization Research Section, activated to investigate the utility of various portions of the radio frequency spectrum, will study the factors that affect radio system performance, and advise agencies throughout the United States on the usefulness of the various radio frequency bands for their specific applications.

Chester Peterson has joined the Bureau staff as a physicist in the Resistance Measurements Section, bringing a wide background of experience in the fields of electrical engineering, physics, and metallurgy, in both Government and industry. Mr. Peterson will assist with the completion of an absolute measurement of resistance, work on which was interrupted by the war, and will undertake research on electrical resistance alloys suitable for the preparation of improved precision resistance standards.

Dr. Homer D. Holler has returned to the staff of the Bureau's Underground Corrosion Section from the Westinghouse Electric Corporation, where he has been engaged in corrosion investigations and other chemical research. Because of wide experience in the field of electrochemistry, Dr. Holler will initiate a new phase of the underground corrosion studies that the Bureau has been conducting for many years. Utilizing the extensive engineering data accumulated in these studies, the program will be directed toward the more fundamental electrochemical aspects of underground corrosion.

New and Revised Publications Issued During January 1947

Journal of Research [1]

Journal of Research of the National Bureau of Standards, volume 38, number 1, January 1947 (RP1758 to RP1764, inclusive). Price 30 cents. Annual subscription, 12 issues, $4.50.

Research Papers [1]

RP1747. Equilibrium constants of some reactions involved in the production of 1,3-butadiene. Ferdinand G. Brickwedde, Morris Moskow, and John G. Aston. Price 10 cents.

RP1748. Effect of catalysts and pH on strength of resin-bonded plywood. Gordon M. Kline, Frank W. Reinhart, Royden C. Rinker, and Nicholas J. DeLollis. Price 15 cents.

RP1749. Purification of sodium chloride and potassium chloride for use in electrochemical work, and the determination of small amounts of bromide. Gladys D. Pinching and Roger G. Bates. Price 10 cents.

RP1750. Preparation of mannuronic lactone from algin. Harriet L. Frush and Horace S. Isbell. Price 10 cents.

RP1751. Experimental manufacture of paper for war maps. Charles G. Weber and Merle B. Shaw. Price 10 cents.

RP1752. Purification, purity, and freezing points of 7 heptanes, 16 octanes, 6 pentenes, cyclopentene, and 7 C_9H_{12} alkylbenzenes of the API-Standard and API-NBS series. Anton J. Streiff, Evelyn T. Murphy, Vincent A. Sedlak, Charles B. Willingham, and Frederick D. Rossini. Price 20 cents.

RP1753. Carrier-distillation method for spectrographic analysis and its application to the analysis of uranium-base materials. Bourdon F. Scribner and Harold R. Mullin. Price 10 cents.

RP1754. Vacuum-tube acceleration pick-up. Walter Ramberg. Price 15 cents.

RP1755. Comparative bond efficiency of deformed concrete reinforcing bars. Arthur P. Clark. Price 10 cents.

RP1756. Development of a hydrochloric acid process for the production of alumina from clay. James I. Hoffman, Robert T. Leslie, Harold J. Caul, Lewis Jesse Clark, and John Drake Hoffman. Price 15 cents.

RP1757. Study of Ofner's method for the determination of invert sugar. Emma J. McDonald and Anne L. Turcotte. Price 10 cents.

Circulars [1]

C456. Magnetic testing. Raymond L. Sanford. Price 10 cents.

C457. Weights per United States gallon and weights per cubic foot of sugar solutions. Carl F. Snyder and Lester D. Hammond. Price 10 cents.

Building Materials and Structures Report [1]

BMS107. Building-code requirements for new dwelling construction. Price 20 cents.

Simplified Practice Recommendation [1]

R21–46. Lavatory and sink traps. (Supersedes R21). Price 5 cents.

Commercial Standard [1]

CS136–46. Blankets for hospitals. Price 5 cents.

Basic Radio Propagation Predictions [1]

CRPL–D29. Basic radio propagation predictions for April 1947 three months in advance. Issued January 1947. Price 15 cents. Annual subscription, 12 issues, $1.50.

Technical News Bulletin [1]

Technical News Bulletin, volume 31 number 1, January 1947. Price 10 cents. Annual subscription, 12 issues, $1.00.

Mimeographed Material

Letter Circulars

(Letter Circulars are prepared to answer specific inquiries addressed to the National Bureau of Standards, and are sent only on request to persons having a definite need for the information. The Bureau cannot undertake to supply lists or complete sets of Letter Circulars or send copies automatically as issued.)

LC843. Publications relating to building codes and construction practice—home building—building material specifications—home maintenance. (Supersedes LC811.)

LC844. List of simplified practice recommendations. Revised to February 1, 1947. (Supersedes LC826.)

Recent Articles by Members of the Bureau's Staff Published in Outside Journals [2]

New condensation products of formaldehyde with amides and amines. Dr. H. Scheurmann, I. G. Farbenindustrie A.–G., translated by Irma G. Callomon and G. M. Kline. The Paper Industry and Paper World (59 E. Van Buren St., Chicago 5, Ill.) **28**, No. 10, 1495 (January 1947).

Voluntary standards adopted by the trade. F. W. Reynolds. Domestic Commerce (Department of Commerce, Washington 25, D. C.) **34**, No. 11, 3 (November 1946).

How standards are established. F. W. Reynolds. Apparel Manufacturer (1133 Broadway, New York 10, N. Y.) **23**, No. 12, 86 (December 1946).

Quality standardization—asset to industry. H. A. Ehrman. Daily News Record (8 E. 13th St., New York 3, N. Y.) p. 8, Sec. 2 (January 28, 1947).

Apparel sizing standards are practical. M. Lonie. Western Apparel Industry (1118 E. 8th St., Los Angeles 21, Calif.) p. 5, (December 1946).

Defining size—the first step in apparel standardization. M. Lonie. National Retail Dry Goods Association Bulletin (100 W. 31st St., New York, N. Y.) **29**, No. 1, 14 (January 1947).

Oxygen boost of engine power at altitude. Francis Masi, Ernest F. Fiock, and Lieut. Com. Robert A. Grosselfinger USNR. Society of Automotive Engineers Quarterly Transactions (29 W. 39th St., New York 18, N. Y.) **1**, No. 1, 76 (January 1947).

Thermodynamic properties of gaseous 1,3-butadiene and the normal butenes above 25° C. John G. Aston, George Szasy, Harold W. Woolley, and Ferdinand G. Brickwedde. J. Chem. Phys. (57 E. 55th St., New York 22, N. Y.) **14**, 67 (1946).

Determination and presentation of compressive stress-strain data for thin sheet metal. Walter Ramberg and James A. Miller. Journal of Aeronautical Sciences (2 E. 64th St., New York 21, N. Y.) **13**, No. 11, 569 (November 1946).

Molding sand fineness test. Margaret Price and A. I. Krynitsky. American Foundryman (222 W. Adams St., Chicago 6, Ill.) **10**, No. 6, 24 (December 1946).

Thermal-expansion stresses in reinforced plastics. P. S. Turner. Modern Plastics (122 E. 42d St., New York 17, N. Y.) **24**, No. 4, 153 (December 1946).

Brazil's program for the production of natural rubber. Norman Bekkedahl. Revue Generale du Caoutchouc (42 Rue Scheffer, Paris 16, France) **23**, No. 10, 241 (October 1946).

The concentration of ^{39}K and ^{41}K by balanced ion migration in a counterflowing electrolyte. A. Keith Brewer, S. L. Madorsky, and J. W. Westhaver. Science (1515 Mass. Ave., Washington 5, D. C.) **104**, 156 (August 16, 1946).

Vulcanization of GR-S by the Peachy process. Archibald T. McPherson. Rubber Age (250 W. 57th St., New York 19, N. Y.) **59**, No. 3, 323 (June 1946).

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[1] Send orders for publications under this heading only to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Subscription to Technical News Bulletin, $1.00 a year; Journal of Research, $4.50 a year (to addresses in the United States and its possessions and to countries extending the franking privilege); other countries, $1.35 and $5.50, respectively.

[2] These publications are not available from the Government. Requests should be sent direct to the publishers.

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